

SYNTHETIC APERTURE RADAR SIGNAL PROCESSING: TRENDS AND TECHNOLOGIES

VEXCEL
CORPORATION
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JOHN C. CURLANDER

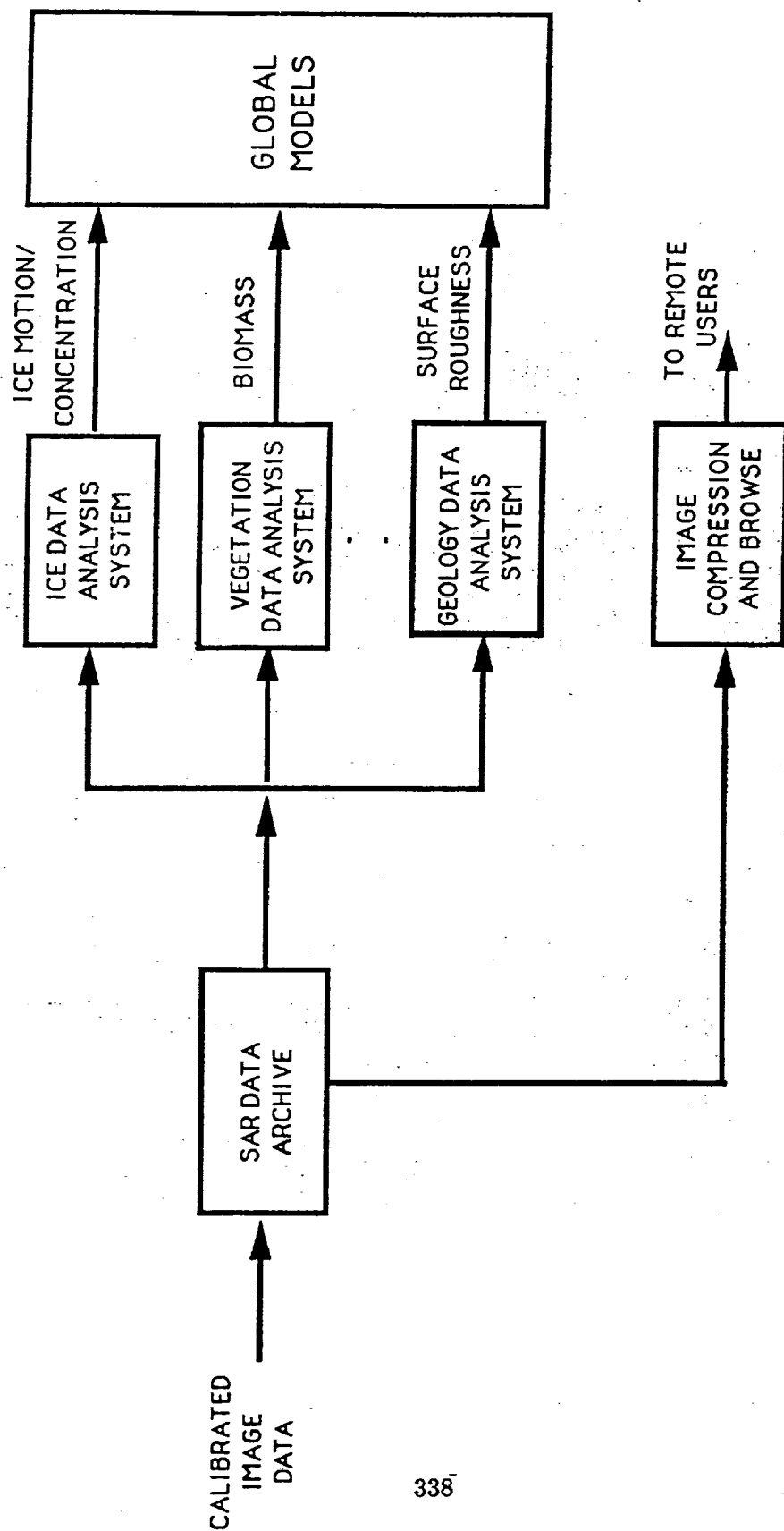
presented at the
3rd SPACEBORNE IMAGING RADAR SYMPOSIUM

JET PROPULSION LABORATORY
PASADENA, CA
JANUARY 20, 1993

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OVERVIEW OF SAR PROCESSING SAR DATA SYSTEM OVERVIEW

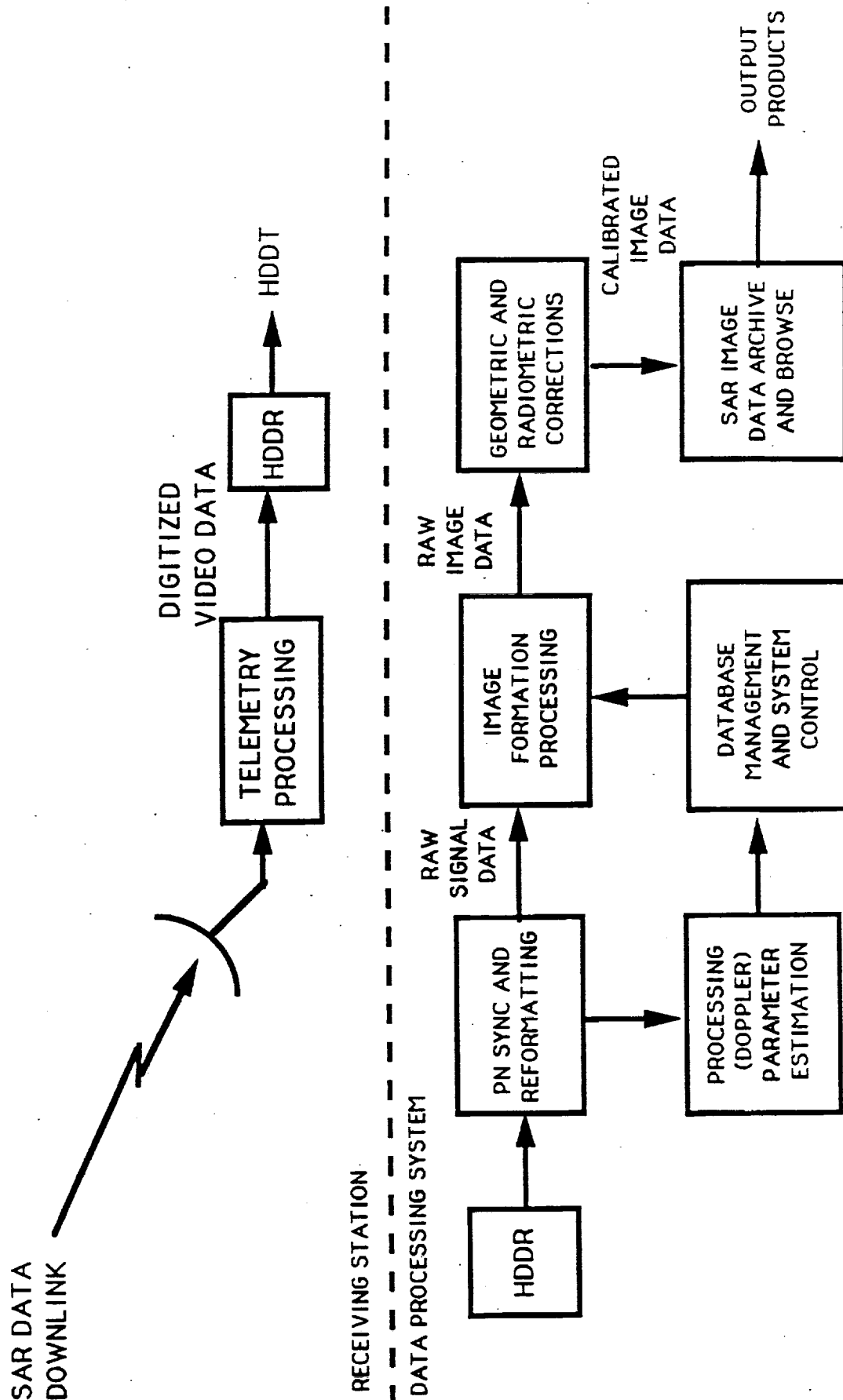


SAR CORRELATOR: TRENDS AND TECHNOLOGIES

OUTLINE

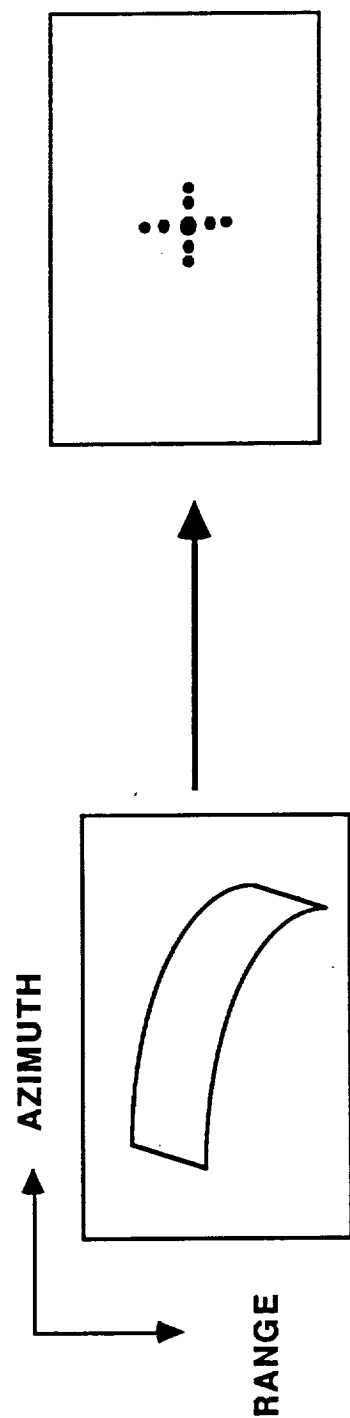
- **OVERVIEW**
 - SAR GROUND DATA SYSTEM
 - SAR SIGNAL PROCESSING ALGORITHMS
 - SAR CORRELATOR ARCHITECTURES
- **CURRENT OPERATIONAL SYSTEM IMPLEMENTATIONS**
 - ARCHITECTURES
 - ALGORITHMS
- **SUMMARY**
 - CURRENT, FUTURE TRENDS

OVERVIEW OF SAR PROCESSING SAR DATA SYSTEM OVERVIEW



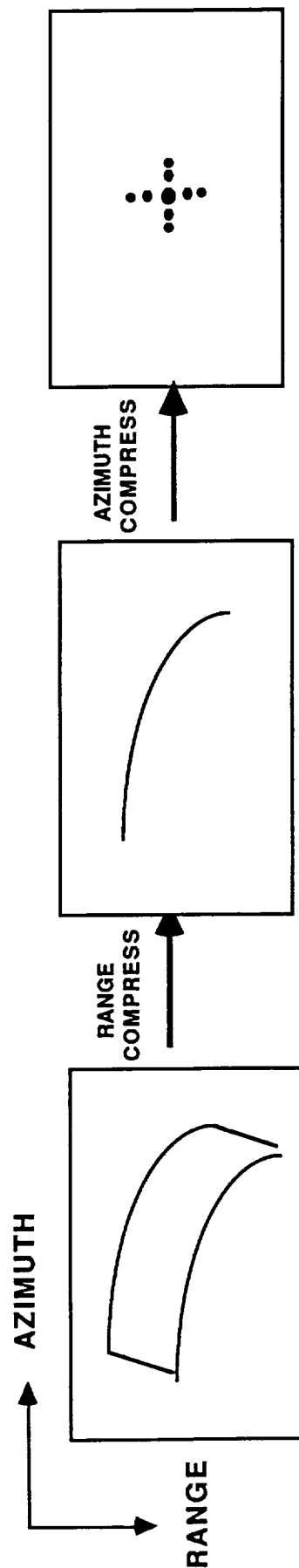
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SAR PROCESSOR ALGORITHM OVERVIEW



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APPROACH 1: APPLY 2-D FILTER TO COMPENSATE FOR PHASE DISPERSION



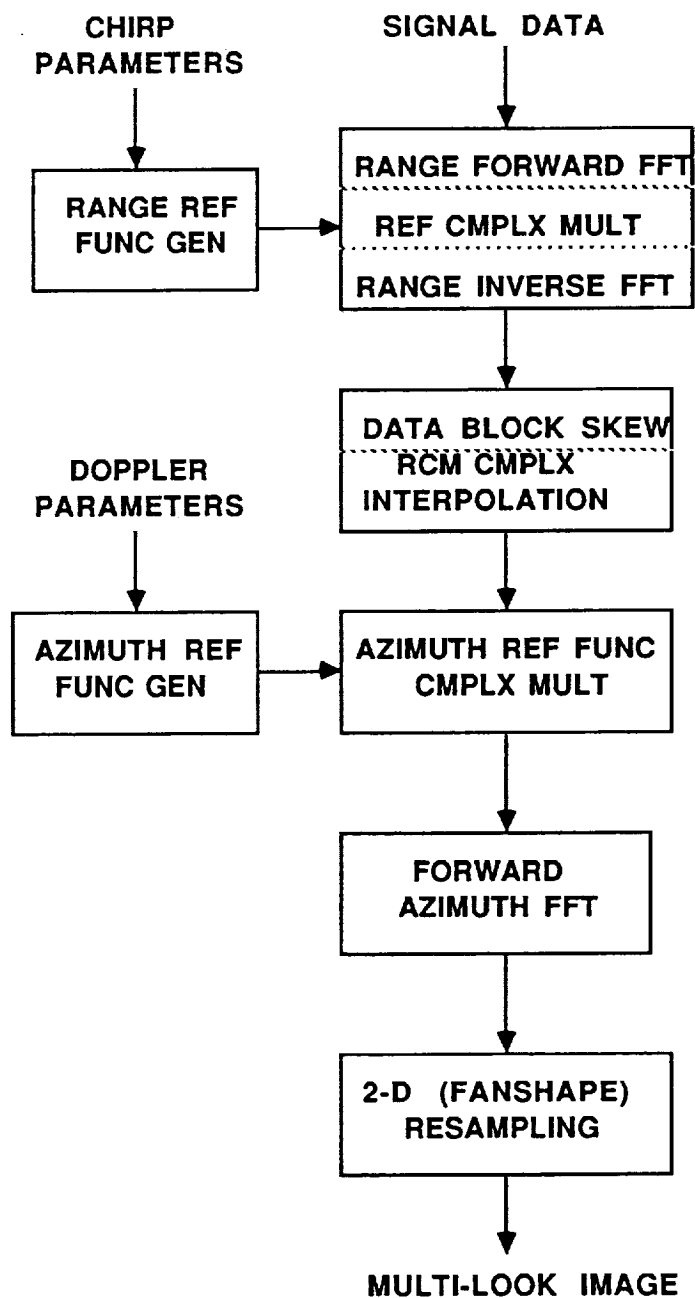
APPROACH 2: APPLY TWO 1-D FILTERS FORMING A RANGE COMPRESSED IMAGE

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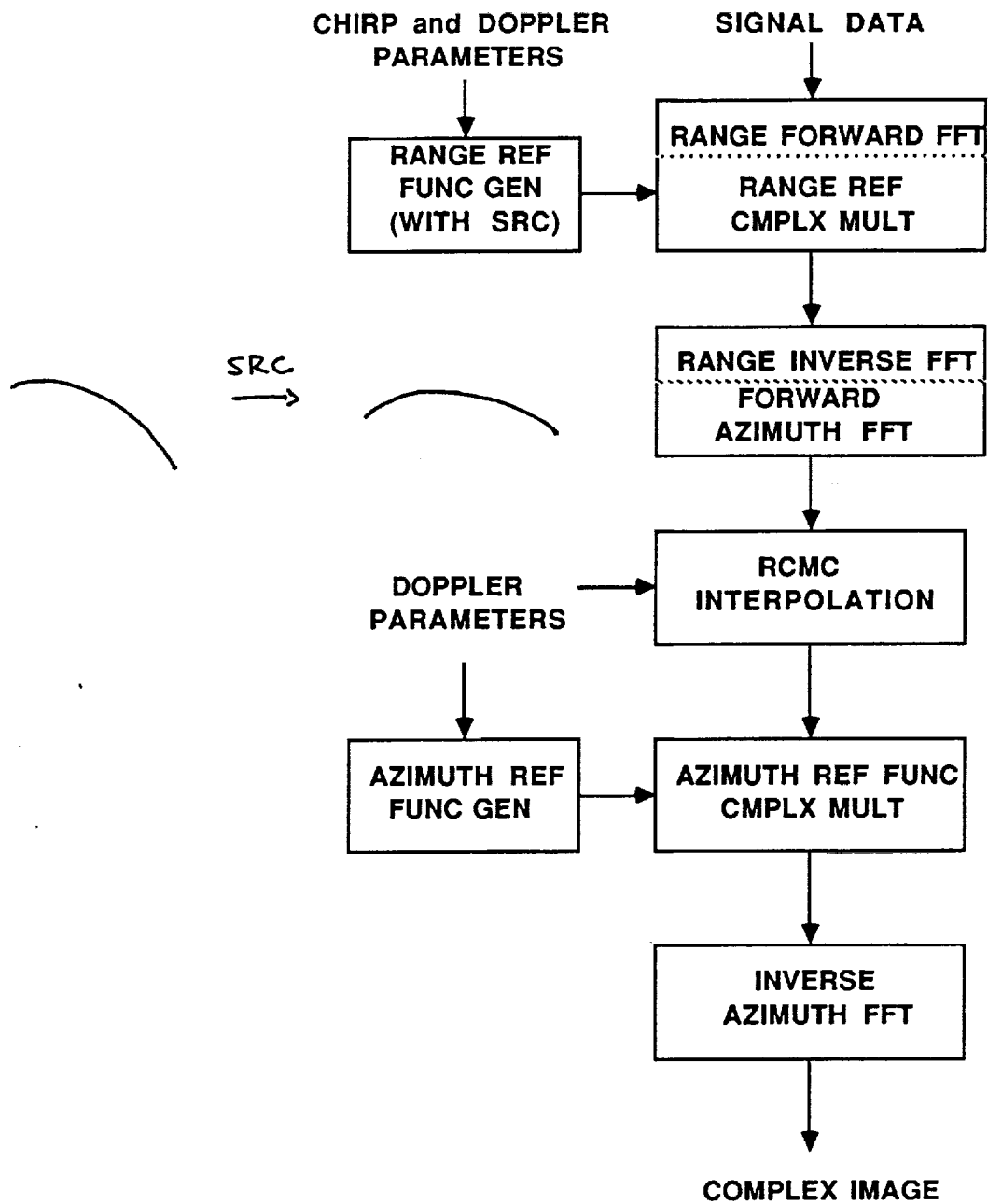
ALGORITHM OVERVIEW

- **SPECTRAL ANALYSIS ALGORITHMS**
 - COMPUTATIONALLY EFFICIENT, GOOD IMAGE QUALITY FOR SMALL TIME-BANDWIDTH PRODUCTS, CANNOT ACHIEVE FULL AZIMUTH RESOLUTION, VARIABLE SNR ACROSS IMAGE BLOCK
 - SPECAN (DERAMP/FFT): SCANSAR, BURST MODE RADARS
 - POLAR ALGORITHM: MILITARY APPLICATIONS, HIGH SQUINT, SMALL PATCH
- **RANGE/DOPPLER ALGORITHMS**
 - FULL AZIMUTH RESOLUTION, GOOD IMAGE QUALITY FOR MODERATE SQUINT, PROVEN ALGORITHM FOR SPACEBORNE SAR, EASY PREPROC AND MOCOMP, POOR PERFORMANCE ON HIGH SQUINT AND HIGH RESOLUTION SAR
 - SECONDARY RANGE COMPRESSION (SRC): BROADSIDE, STRIP IMAGERS
 - SQUINT IMAGING MODE (SIM): STRIP IMAGERS SQUINT UP TO 20 DEGREES
- **2D TRANSFORM (WAVE DOMAIN) ALGORITHMS**
 - BEST APPROX, EXCELLENT PHASE FIDELITY, LITTLE OR NO INTERPOLATION, UNPROVED IN OPERATIONAL SYSTEMS, DIFFICULT PREPROC AND MOCOMP, APPLICATION IN INTERFEROMETRY AND POLARIMETRY
 - WAVE EQUATION: HIGH SQUINT (75 DEGREES), PHASE PRESERVING
 - CHIRP SCALING: REQUIRES LINEAR FM CHIRP, NO INTERPOLATION

SPECAN ALGORITHM FLOWCHART

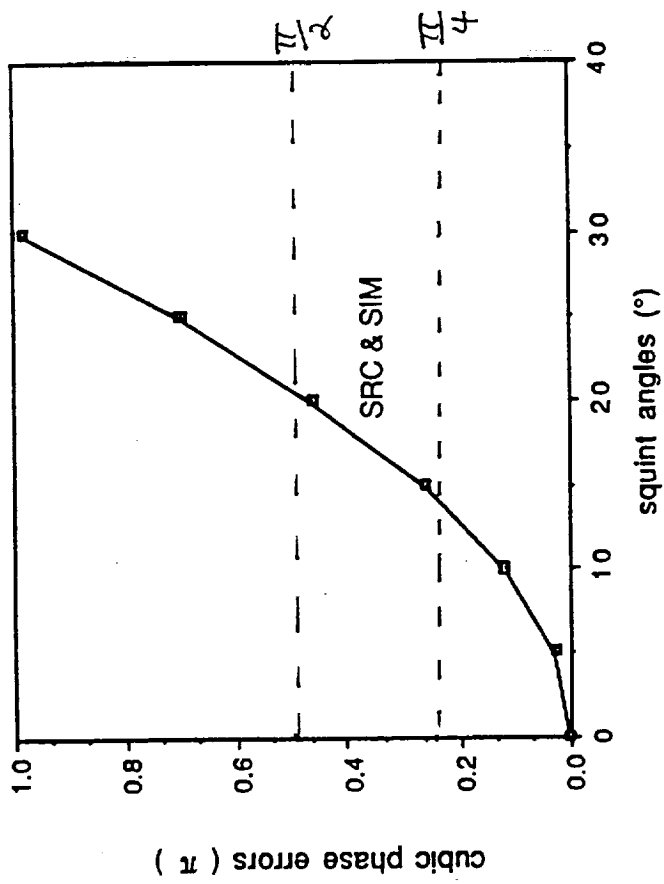
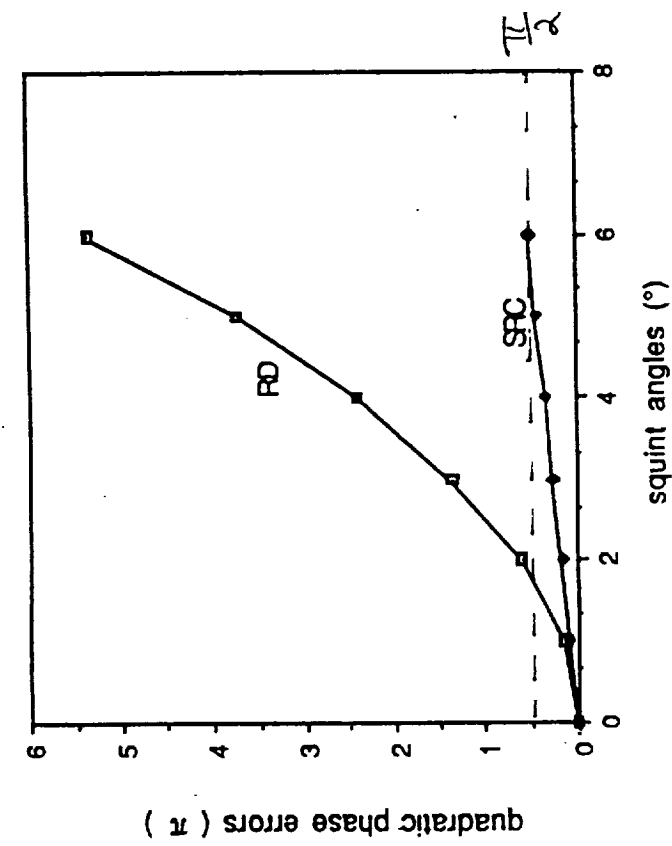


RANGE/DOPPLER ALGORITHM FLOWCHART WITH SECONDARY RANGE COMPRESSION (SRC)



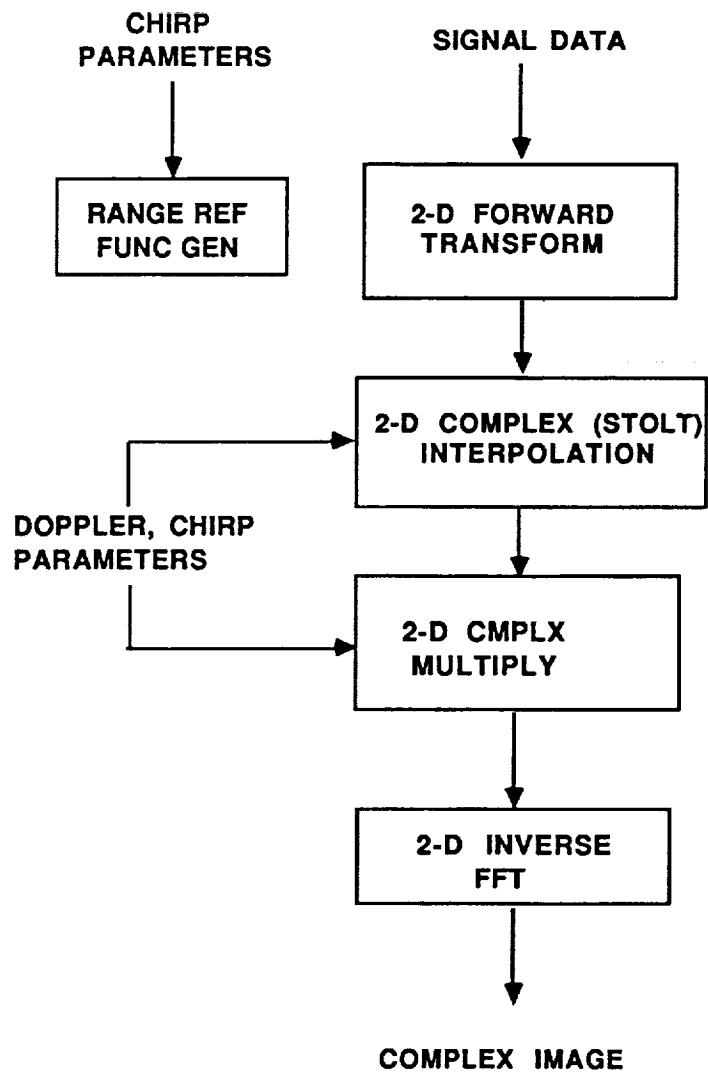
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RANGE DOPPLER ALGORITHM PERFORMANCE



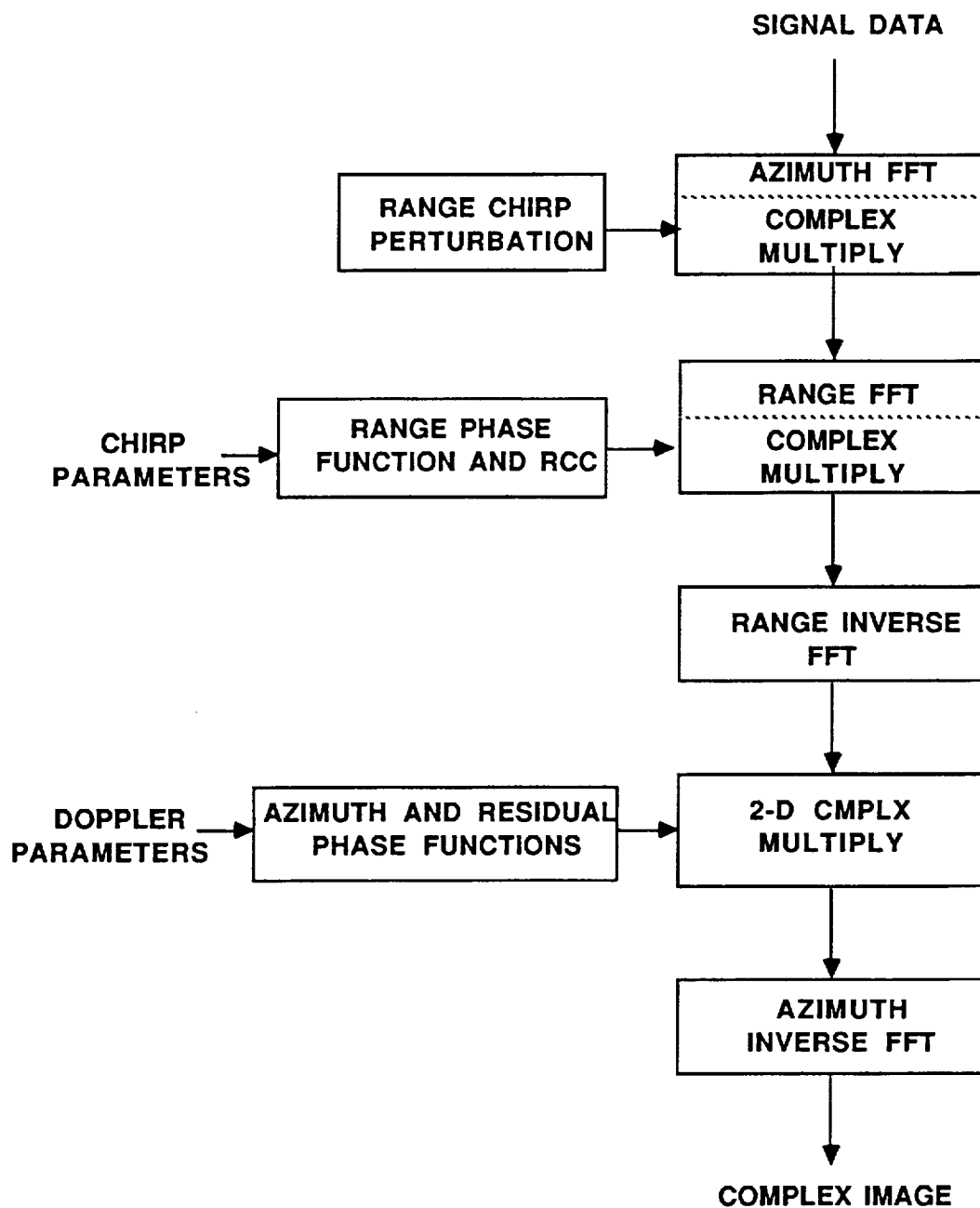
- RESIDUAL PHASE ERRORS FOR THE SECONDARY RANGE COMPRESSION (SRC) AND THE SQUINT IMAGING MODE (SIM) ALGORITHMS (CHANG, ET AL, 1992)

2-D TRANSFORM (WAVE EQUATION) ALGORITHM FLOWCHART



ROCCA, 1987; CAFFORIO, 1991

2-D TRANSFORM (CHIRP SCALING) ALGORITHM FLOWCHART



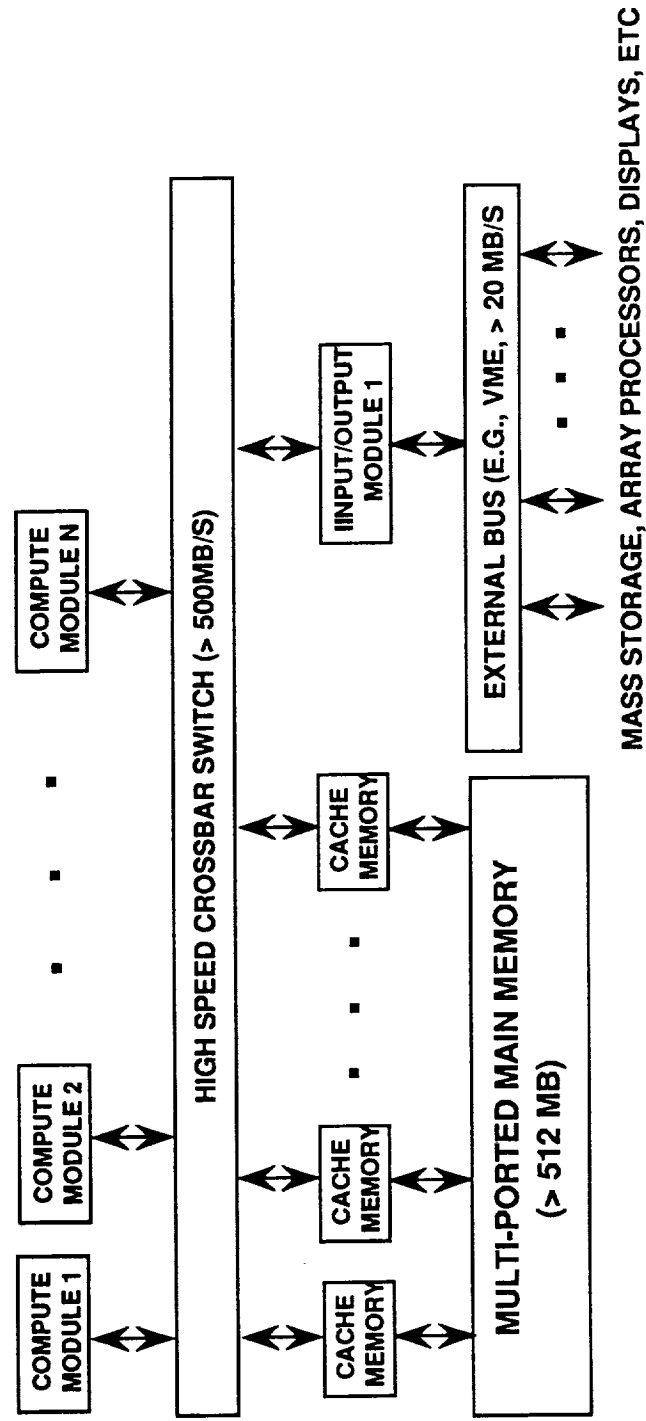
RANEY, 1991

SAR CORRELATOR: TRENDS AND TECHNOLOGIES ARCHITECTURE OVERVIEW

- **COMMON NODE**
 - USED IN MOST OPERATIONAL SAR PROCESSORS, SHARED MAIN MEMORY, LOW COST, PORTABLE S/W, CONSTRAINED BY NODE (BUS, SWITCH) BANDWIDTH
 - GENERAL PURPOSE COMPUTERS (WITH ACCELERATORS): WORKSTATIONS
 - CUSTOM ARCHITECTURES: COMMON SIGNAL PROCESSOR
- **PIPELINE**
 - LIMITED APPLICATION PROCESSOR (ONE PRODUCT), BEST ARCHITECTURE FOR REAL-TIME PROCESSING, NOT EASILY ADAPTABLE TO NEW PRODUCTS OR SENSORS, SINGLE FAILURE SHUTDOWN
 - ADVANCED DIGITAL SAR PROCESSOR (ADSP): JPL BUILT FOR SEASAT, MGN
 - AIRBORNE SAR PROCESSORS: QUICK-LOOK ON-BOARD, KRAS, LORAL
- **MASSIVELY PARALLEL**
 - UNLIMITED COMPUTATIONAL CAPACITY, GRACEFUL DEGRADATION, LOW COST PER PROCESSOR, DIFFICULT I/O, COMPLEX SOFTWARE DEVELOPMENT, FUTURE FOR ALL LARGE COMPUTATION TASKS
 - MIMD (DUAL PARALLELISM): THINKING MACHINES CM-5, INTEL I-WARP
 - SIMD MACHINES: DEC MASSPAR

SAR CORRELATOR ARCHITECTURES

1) GENERAL PURPOSE COMPUTERS WITH (OR WITHOUT) SPECIAL PROCESSORS



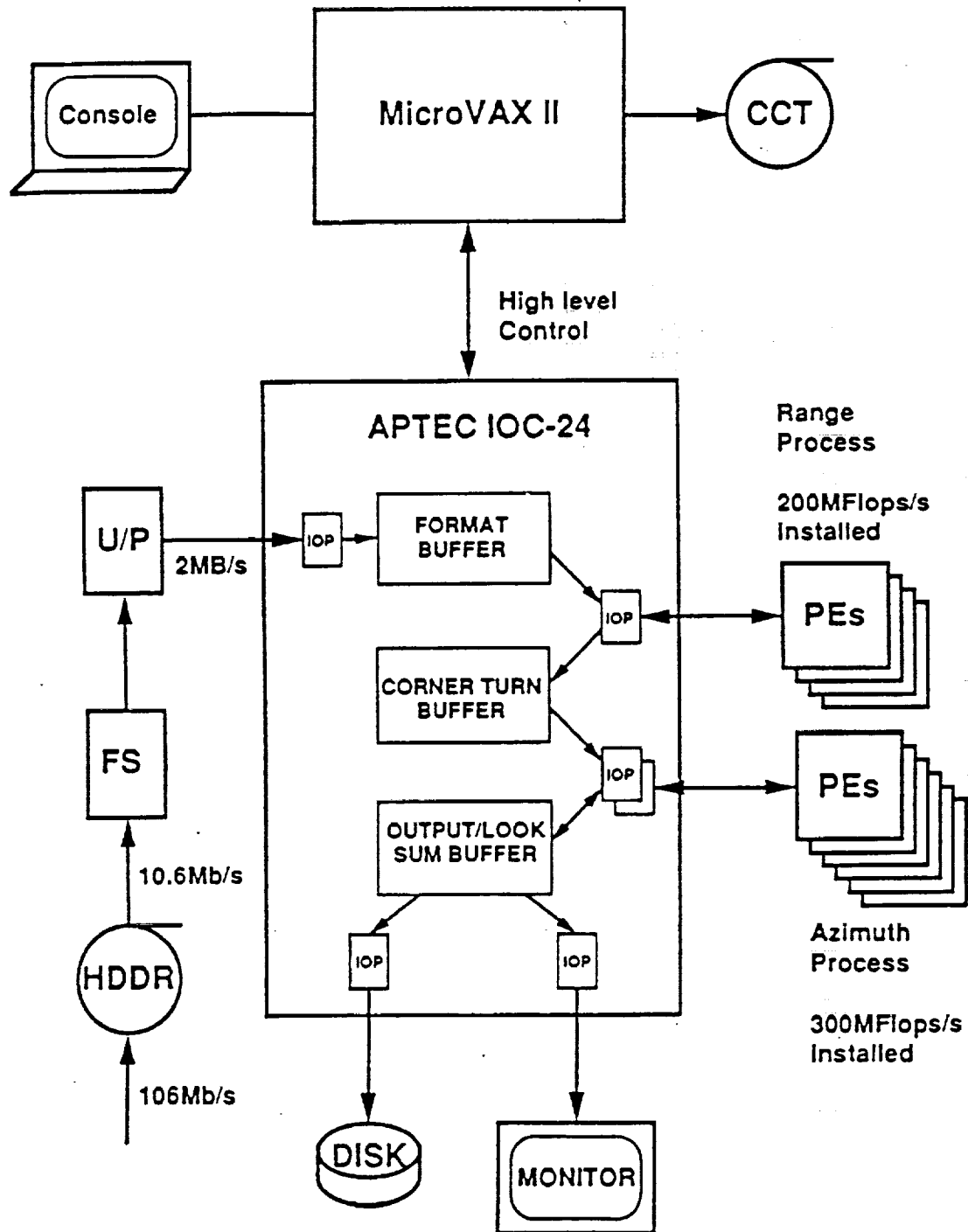
- **ADVANTAGES**

- HIGH LEVEL OPERATING SYSTEM (SIMPLE TO PROGRAM), SOFTWARE STANDARDS/PORTABILITY

- **DISADVANTAGES**

- HIGH COST PER MFLOP, PERFORMANCE LIMITED BY CENTRAL BUS DATA RATE

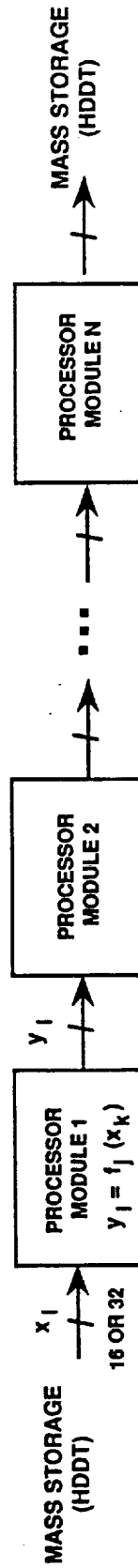
ADVANCED SAR CORRELATOR ARCHITECTURE BRITISH AEROSPACE ERS-1 PROC



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SAR CORRELATOR ARCHITECTURES

II) CUSTOM PIPELINE PROCESSORS

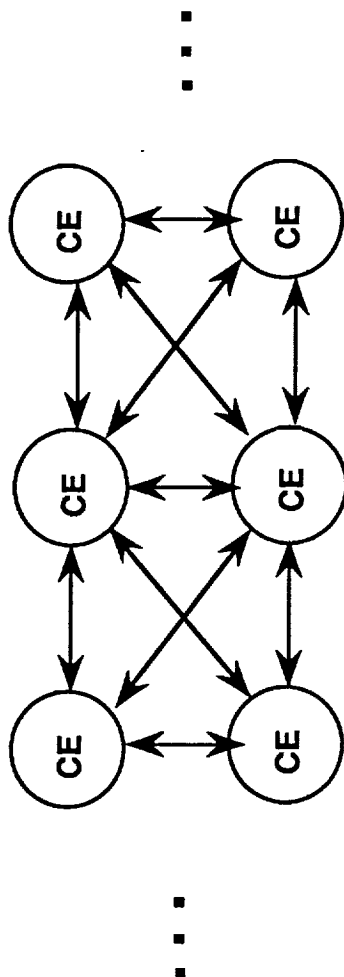


- ADVANTAGES
 - OPTIMUM ARCHITECTURE FOR SAR IN TERMS OF THROUGHPUT, LOW COST/MFLOP
- DISADVANTAGES
 - INFLEXIBLE ARCHITECTURE, NO GRACEFUL DEGRADATION, TYPICALLY REQUIRES ALGORITHM APPROXIMATIONS

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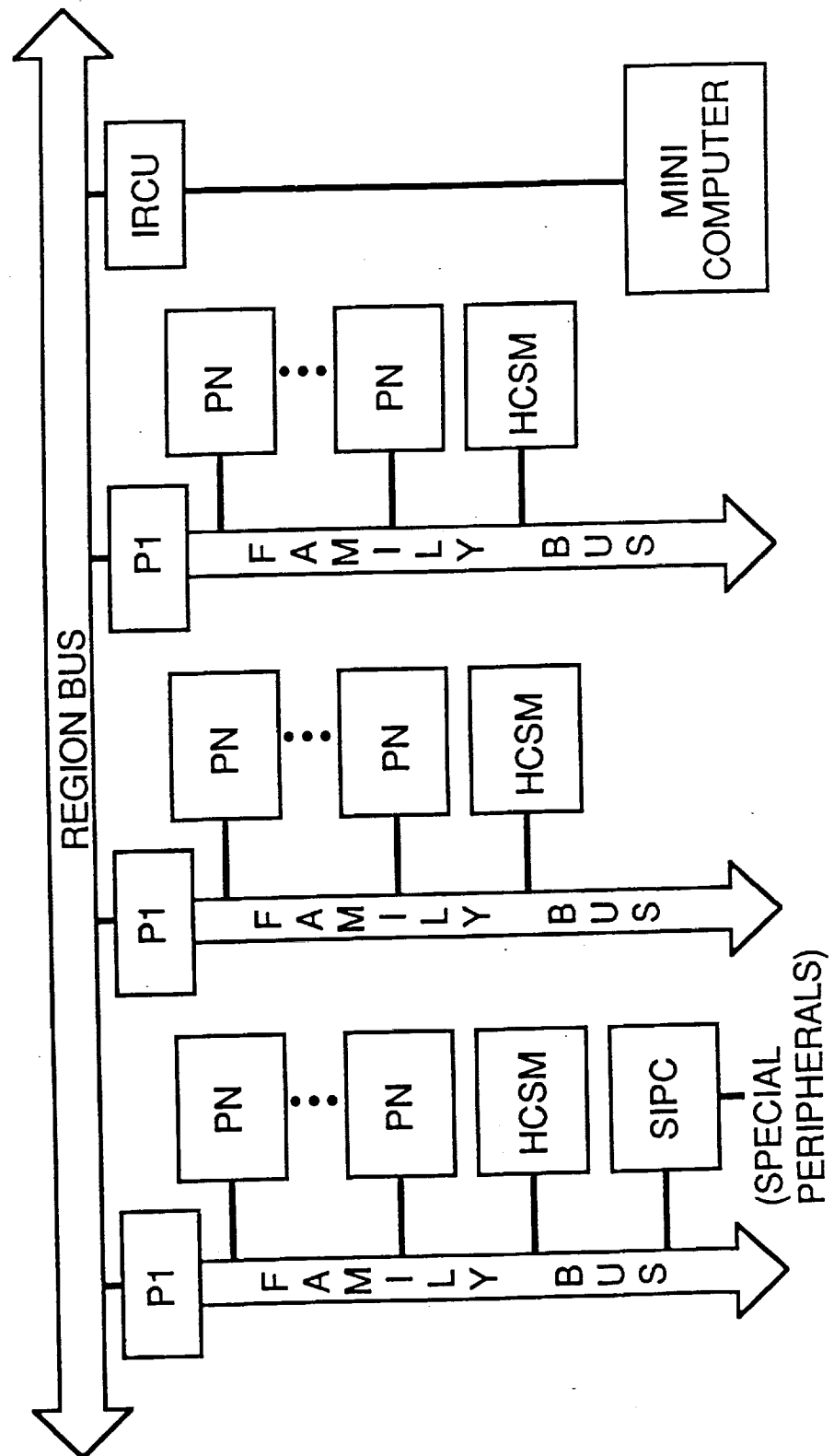
SAR CORRELATOR ARCHITECTURES

III) MASSIVELY PARALLEL PROCESSORS



- **ADVANTAGES** - LOW COST/MFLOP, UNLIMITED SYSTEM EXPANDABILITY, HIGH RELIABILITY
- **DISADVANTAGES** - PRIMITIVE OPERATING SYSTEMS, REQUIRES SPECIAL ALGORITHMS FOR EFFICIENCY, POOR I/O TO EACH PROCESSOR

SAR CORRELATOR DESIGN EMMA MIMD CONCURRENT ARCHITECTURE



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OPERATIONAL SAR PROCESSING SYSTEMS

ARCHITECTURES

- COMMON NODE
 - ERS-1 FAST DELIVERY PROCESSORS, AUSTRALIA PAF, CANADA PAF, GERMANY PAF AND X-SAR
- PIPELINE
 - ERS-1/JERS-1 ALASKA SAR FACILITY, MAGELLAN
- MASSIVELY PARALLEL
 - ITALY PAF, NASA/JPL SIR-C

ALGORITHMS

- SPECAN
 - NASA/JPL MAGELLAN, RADARSAT SCANSAR, NASA/JPL SIR-C SURVEY PROCESSOR
- RANGE/DOPPLER
 - ERS-1 PAF AND FAST DELIVERY PROCESSORS
 - NASA/JPL SEASAT, SIR-B AND SIR-C PRECISION PROC
 - DLR XSAR, ASF ERS-1 AND JERS-1, NASDA JERS-1
- 2-D TRANSFORM
 - RESEARCH PROCESSORS: ESA, CCRS, JPL, DLR

SAR CORRELATOR: TRENDS AND TECHNOLOGY

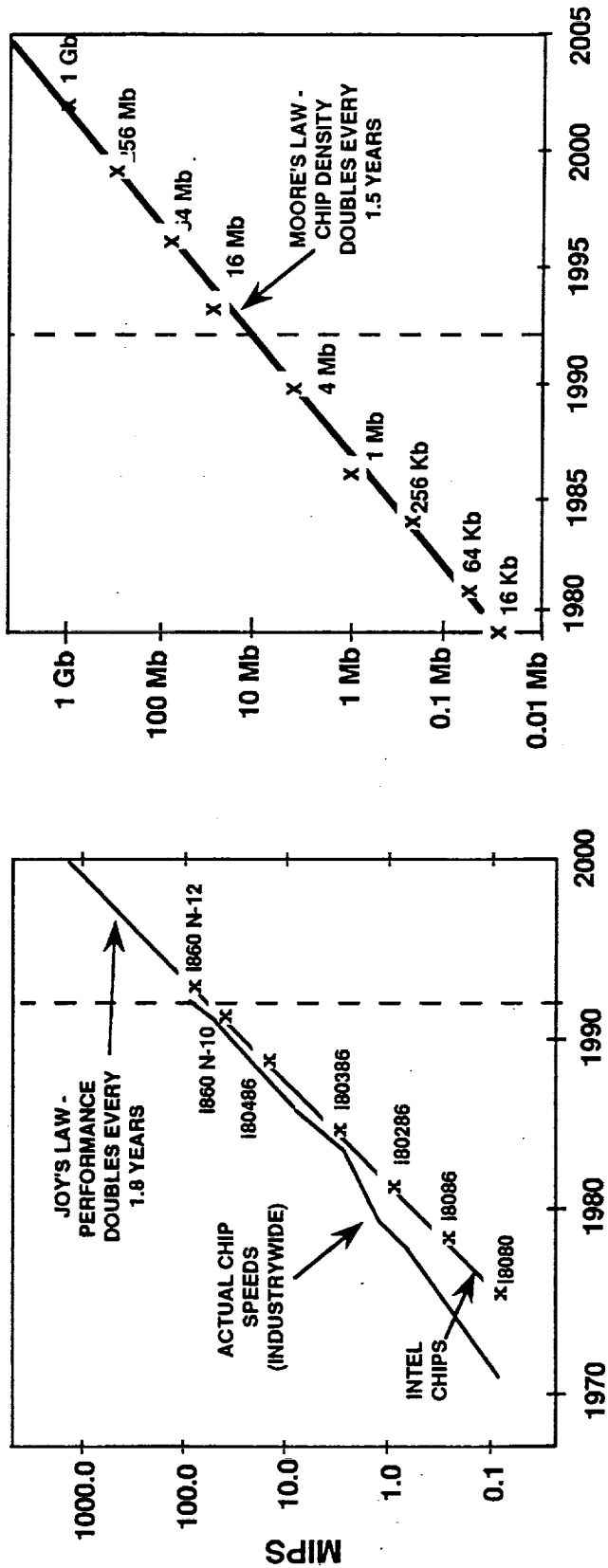
PROJECTED HARDWARE NEEDS/PERFORMANCE

JPL PROCESSOR HARDWARE REQUIREMENTS*

	INPUT DATA RATE (MBps)	DATA VOLUMES (Gsamples/DAY)	COMPUTATIONAL CAPACITY (GFLOPS)	MAIN MEMORY (MB)
AIRSAR	0.5	5	0.2	400
SIR-C	0.8	10	0.3	500
RADARSAT	1.2	57	0.8	750
EOS SAR	6.0	173	3.3	900

* ASSUME 10 SHIFT PER WEEK OPERATIONS WITH 50% REPROCESSING

MICROPROCESSOR PERFORMANCE AND MEMORY CHIP CAPACITY EVOLUTION



SAR CORRELATOR: TRENDS AND TECHNOLOGIES SUMMARY

- **CURRENT OPERATIONAL SYSTEMS (PAST 5 YEARS TO PRESENT)**
 - **ALGORITHMS: RANGE/DOPPLER**
 - **ARCHITECTURES: COMMON NODE**
- **FUTURE OPERATIONAL SYSTEMS (PRESENT TO NEXT 5 YEARS)**
 - **ALGORITHMS: 2D TRANSFORM**
 - **ARCHITECTURES: MASSIVELY PARALLEL**
- **DATA SYSTEM SUCCESSES (PAST 5 YEARS)**
 - **RADIOMETRIC/POLARIMETRIC CALIBRATION**
 - **DATA FORMATS (CEOS)**
 - **RELIABLE CORRELATOR DESIGNS**
- **DATA SYSTEM CHALLENGES (NEXT 5 YEARS)**
 - **END-TO-END OPERATIONS, INCLUDING DATA DISTRIBUTION**
 - **GEOPHYSICAL PROCESSORS, OPERATIONAL REDUCTION OF DATA TO HIGH LEVEL PRODUCTS**
 - **USER INTERACTION IN MISSION OPERATIONS, TELESCIENCE**

